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DETERMINATION OF METAL SPARKING CHARACTERISTICS  
AND THE EFFECTS ON EXPLOSIVE DUST CLOUDS

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ABSTRACT

Of major concern in industry are hazards posed by metal-to-metal sparking in environments where potentially explosive dusts are present. The probability of ignition of a dust cloud by metal sparking is dependent on many factors including the type of metal, the contact speed of the metal surfaces, the contact time of the metal surfaces, the pressure on the contact surface and the type and concentration of the dust cloud present.

Metal sparking tests were performed as part of a hazard analysis program. Safety Consulting Engineers, Inc. conducted for ICI Americas, Inc.

The purpose of the test was to determine the sparking characteristics of a series of metals and the effects of the sparks produced on several types of dust clouds.

## INTRODUCTION

Explosibility tests have been performed in the past to determine the relative destructive output of various types of dusts. Test chambers were used to simulate dust explosion. Figure 1 is a sketch of Bureau of Mines 20-liter chamber equipped with a sample dust dispersion mechanism. The 20-liter chamber was modified to contain the mechanical sparking system. Figure 2 is a sketch of the modified Bureau of Mines 20-liter chamber.

The spherical shape of the 20-liter chamber helps provide a uniform dust suspension. A 7.62 cm (3-inch) diameter by 0.635 cm (1/4-inch) thick 304L stainless steel contact wheel mounted on a shaft, which protrudes through the side wall of the chamber, is driven by an electric motor located outside the chamber. A 0.635 cm (1/4-inch) diameter by 5.08 cm (2-inch) long rod is held by a lever bar against the circumference of the metal wheel. A dead weight of 1362 grams (3 pounds) is located at the outside portion of the lever bar. A viewing window and mirror allowed remote observation of the tester.

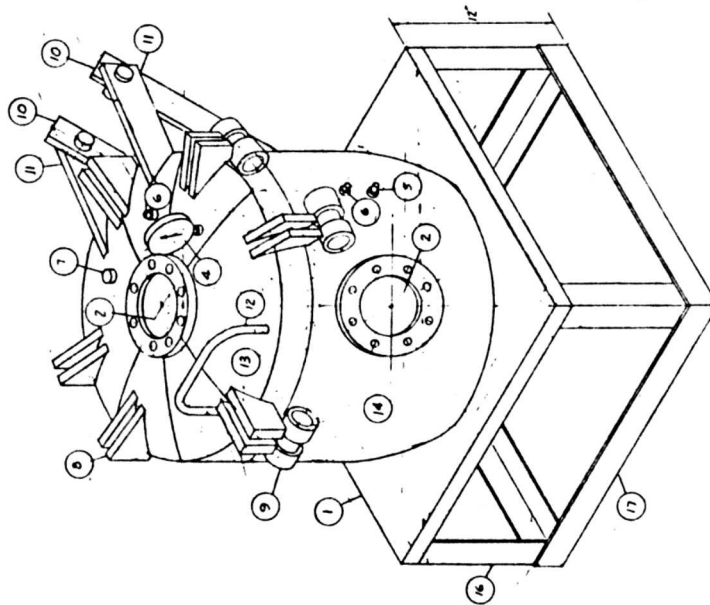
## PROCEDURE

Each rod material/dust combination test was performed as follows. The preweighed dust sample was first placed in the bottom of the chamber. The rod material was raised using a pulley mechanism before the test chamber was closed. The electric motor was turned on to start the contact wheel. Pressurized air from the test chamber nozzle dispersed the sample dusts uniformly while the rod material was dropped to make contact with the rotating wheel. Ignition of the dust cloud was then observed through the view mirror. The setup is illustrated in Figure 3.

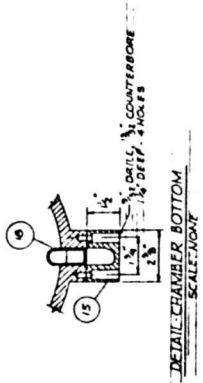
## TEST RESULTS

The first series of tests consisted of testing six metal rods to determine the minimum contact wheel speed which would produce sparking for each rod. The following metal rods were tested: 1018 Mild Steel, 316 Stainless Steel, 304 Stainless Steel, 304L Stainless Steel, 3003-H14 Aluminum and 6061-T6 Aluminum. By determining the minimum wheel rotation speed that produced sparking for each one of the metal rods tested, the types of metals more likely to produce sparking were identified. Table 1 contains results of these tests and shows that 304 Stainless Steel rod produced sparking at the lowest wheel speed. Neither aluminum rods produced no sparking at the maximum wheel speed available.

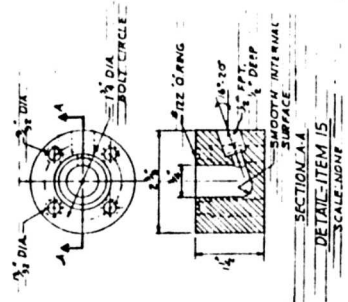
LIST OF MATERIALS	
ITEM	DESCRIPTION
1	1 SUPPORT PLATE 14" X 14" X 1/2" THICK S.S. B.
2	2 1/2" DIA. 3/16" S.S. PLATE
3	1 1/2" DIA. 3/16" S.S. PLATE
4	1 1/2" DIA. 3/16" S.S. PLATE
5	1 1/2" DIA. 3/16" S.S. PLATE
6	1 1/2" DIA. 3/16" S.S. PLATE
7	1 1/2" DIA. 3/16" S.S. PLATE
8	1 1/2" DIA. 3/16" S.S. PLATE
9	1 1/2" DIA. 3/16" S.S. PLATE
10	1 1/2" DIA. 3/16" S.S. PLATE
11	1 1/2" DIA. 3/16" S.S. PLATE
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16	1 1/2" DIA. 3/16" S.S. PLATE
17	1 1/2" DIA. 3/16" S.S. PLATE
18	1 1/2" DIA. 3/16" S.S. PLATE



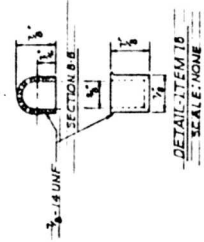
CHAMBER ASSEMBLY  
SCALE: NONE



DETAIL-CHAMBER BOTTOM  
SCALE: NONE



SECTION A-A  
DETAIL-ITEM 15  
SCALE: NONE



SECTION B-B  
DETAIL-ITEM 18  
SCALE: NONE

NOTED	IN R. L. L. L.
DATE	JAN 17, 1945
BY	J. L. L. L.
FOR	20-LITER DIS. EXPLOSION CHAMBER
ASSEMBLY DETAILS & LIST OF MATERIALS	

Figure 1. U. S. Bureau of Mines 20-liter chamber.

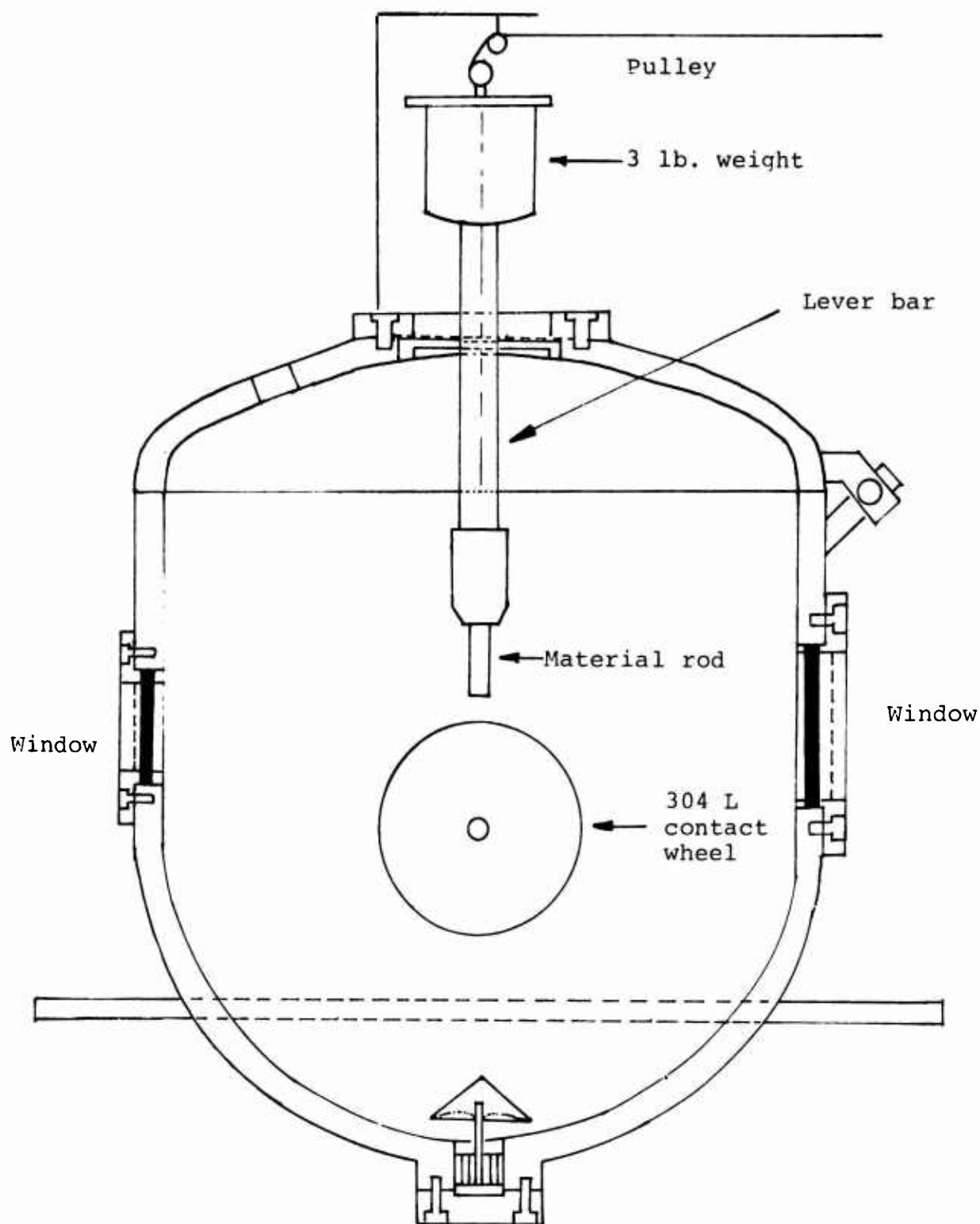


Figure 2. Modified Bureau of Mines 20-liter chamber.

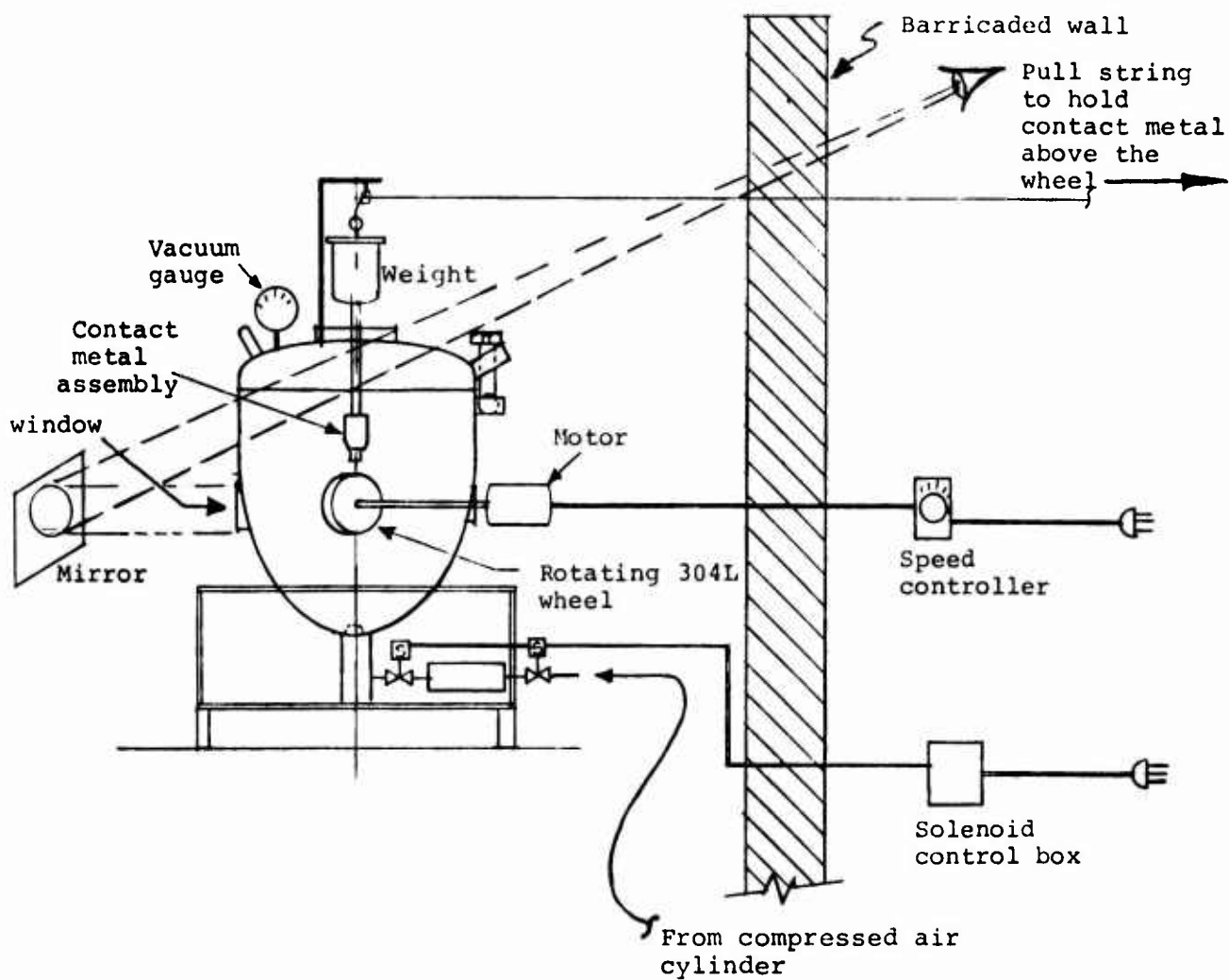


Figure 3. Metal sparking test setup.

After the minimum sparking speeds were found, five different propellant dusts, M6, M30Al, M31Al, CBI, Black Powder, one carbonaceous dusts, Pittsburgh coal dust and one commercial product, cornstarch, were tested to determine the minimum sparking speed for each rod type that would ignite each sample dust. The sample materials tested were ground and sieved through mesh screen (-200 and -100). Table 2 lists the minimum sparking speed for each rod tested that would ignite each sample dust. Results of testing indicated that 1018 Mild Steel was the material aluminum rods failed to produce sparking at low speeds, these materials did not ignite the sample dusts.

The third test series was conducted at a peripheral wheel speed of 14.0 meter/sec ( $\approx 45.8$  ft/sec) for all rod material-sample dust combinations. This test series allowed a ranking of the sample dusts based on ignition sensitivity. The most sensitive dust was M6 propellant with sensitivity decreasing respectively for CBI, cornstarch, M30Al, M31Al, Black Powder and Pittsburgh coal dust. The test rod materials, in order from the most likely to least likely to produce ignition were 1018 Mild Steel, 304L Stainless Steel, 304 Stainless Steel, 316 Stainless Steel, 3003-H-14 Aluminum and 6061-T6 Aluminum. Table 3 illustrates the decreasing ignition sensitivity for the dust samples tested with rods in the order of least likely to produce ignition.

The fourth series of tests consisted of testing all rod material sample dust combinations that produced ignition in the third series of tests, at a peripheral wheel speed of 14.0 meter/sec. The contact time of the rod material and wheel was limited to 0.5 sec. Again this test series allowed a ranking of the sample dusts based on ignition sensitivity during a relatively short exposure to sparking. Table 4 shows that all sample dusts tested ignited when 1018 Mild Steel was used. Cornstarch, CBI, M6 and Black Powder also ignited when tested with 316 Stainless Steel rod.

## CONCLUSIONS

Metal sparking tests, on various metals in several dust cloud environments, showed a distinction between metals that are relatively safer to handle in an explosive dust cloud atmosphere and those that may be unsafe.

Metals found to present a lower sparking hazard include both 3003-H14 and 6061-T6 Aluminum.

Metals tested that are not well suited to an explosive dust cloud atmosphere include 1018 Mild Steel, 304L Stainless Steel, 304 Stainless Steel and 316 Stainless Steel because of their greater tendency to produce sparking.

The potential for explosive dust initiation appears to be greater when contact speed with metals exceeds 9.2 meter/sec (30.1 ft/sec) for 1018 Mild Steel, 8.4 meter/sec (27.5 ft/sec) for 304L Stainless Steel, 7.2 meters/sec (23.6 ft/sec) for 304 Stainless Steel, 7.2 meters/sec (23.6 ft/sec) for 304 Stainless Steel, 8.4 meter/sec (27.5 ft/sec) for 316 Stainless Steel.

At longer metal contact times (with speed greater than the minimum contact speed which would produce sparking for each metal), a greater potential hazard of ignition may also be possible.



TABLE 1  
MINIMUM CONTACT WHEEL SPEED  
WHICH WOULD PRODUCE SPARKING FOR EACH ROD

Contact Force: 13.3 N (3 lbf)

MATERIAL ROD	MINIMUM CONTACT WHEEL SPEED		
	(m/s)	(rpm)	(ft/s)
.018 Mild Steel	9.2	2300	30.1
304L Stainless Steel	8.4	2100	27.5
304 Stainless Steel	7.2	1800	23.6
316 Stainless Steel	8.4	2100	27.5
6003-H14 Aluminum	No visible spark at maximum speed of		
	19.9	5000	65.4
6061-T6 Aluminum	No visible spark at maximum speed of		
	19.9	5000	65.4

TABLE 2

MINIMUM SPARKING SPEED FOR EACH MATERIAL ROD  
THAT WOULD IGNITE THE SAMPLE DUST

SAMPLE DUST TEST	DUST PARTICLE SIZE ( $\mu$ m)	DUST PARTICLE SIZE (in)	SAMPLE DUST CONC. (g/liter)	ROD MATERIAL			
				1018 MILD STEEL	304 STAINLESS STEEL	316 STAINLESS STEEL	3003-H14 ALUMINUM
							6061-T6 ALUMINUM
				MINIMUM SPEED TO CAUSE IGNITION			
				m/s		(ft/s)	
M6	75	0.0029	0.25	12.4 (40.6)	14.0 (45.8)	13.5 (44.5)	-
M30A1	75	0.0029	0.41	11.2 (36.6)	13.2 (43.2)	13.5 (44.5)	-
M31A1	150	0.0059	0.32	10.4 (34.0)	14.0 (45.8)	14.0 (45.8)	-
CBI	150	0.0059	0.41	8.8 (28.3)	14.0 (45.8)	14.0 (45.8)	-
Black Powder	75	0.0029	0.25	11.6 (37.9)	13.2 (43.2)	14.0 (45.8)	-
Pittsburgh coal dust	75	0.0029	0.35	10.0 (32.7)	>19.9 (>65.4)	>19.9 (>65.4)	-
Cornstarch	75	0.0029	0.35	8.0 (26.2)	14.0 (45.8)	14.0 (45.8)	-

- showed no ignition up to a maximum speed of 19.9 m/s (65.4 ft/s)

TABLE 3  
METAL SPARKING TEST RESULTS AT METAL  
WHEEL SPEED OF 14.0 m/s (45.8 ft/s)

SAMPLE DUST TESTED	DUST PARTICLE SIZE ( $\mu$ m)	DUST PARTICLE SIZE (in)	SAMPLE DUST CONC. (g/liter)	ROD MATERIAL (Number of ignitions in 20 runs)					
				1018 MILD STEEL	304L STAINLESS STEEL	304 STAINLESS STEEL	316 STAINLESS STEEL	3003-H14 ALUMINUM	6061-T6 ALUMINUM
M6	75	0.0029	0.25	20	19	18	18	-	-
CBI	150	0.0059	0.41	19	17	18	18	-	-
Cornstarch	75	0.0029	0.35	20	9	7	16	-	-
M30A1	75	0.0029	0.41	19	18	15	15	-	-
M31A1	150	0.0059	0.32	14	13	11	9	-	-
Black powder	75	0.0029	0.25	17	8	6	8	-	-
Pittsburgh coal dust	75	0.0029	0.35	5	-	-	-	-	-

- showed no ignition

TABLE 4

METAL SPARKING TEST RESULTS AT METAL WHEEL SPEED  
OF 14.0 m/s (45.8 ft/s) WITH ROD MATERIAL CONTACT  
TIME OF 0.5 SEC.

SAMPLE DUST TESTED	DUST PARTICLE SIZE ( $\mu$ m)	DUST SIZE (in.)	SAMPLE DUST CONC. (g/liter)	ROD MATERIAL (Number of ignitions in 20 runs)					
				1018 MILD STEEL	316 STAINLESS STEEL	304 STAINLESS STEEL	304L STAINLESS STEEL	3003-H14 ALUMINUM	6061-T6 ALUMINUM
Cornstarch	75	0.0029	0.35	15	10	3	-	-	-
M6	75	0.0029	0.25	12	2	-	-	-	-
CBI	150	0.0059	0.41	10	5	-	-	-	-
Black Powder	75	0.0029	0.25	10	2	-	-	-	-
M31A1	150	0.0059	0.32	9	-	-	-	-	-
M30A1	75	0.0029	0.41	8	-	-	-	-	-
Pittsburgh coal dust	75	0.0029	0.35	-	-	-	-	-	-

- showed no ignition